USE OF AN EXPERT SYSTEM IN THE BOARD SELECTION PROCESS

BY

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USAWC STRATEGY RESEARCH PROJECT

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ABSTRACT

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The purpose of this study was to begin the development and testing of an Expert System (ES) to screen officer personnel records being considered for Command and General Staff College (CGSC). The project included a review of the artificial intelligence (AI) literature relevant to the military and human resource management, problem selection, knowledge acquisition, knowledge representation, knowledge encoding, and knowledge testing and evaluation. The AI computer language PROLOG was used to develop a basic rule-based expert system. Data from 15 mock officer personnel records obtained from US Army Total Personnel Command (PERSCOM) were entered into Board Expert (BOARDEX). Results from BOARDEX were correlated to votes generated by a board consisting of ten human experts from the US Army War College Class of 1996. Numerous statistically significant correlations were found between the members of the board as well as between the human experts and BOARDEX ($r = .6614$, $p = .007$).

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Context of the Study

The United States Army has recently completed roughly 95 percent of the largest manpower draw down in its history. As the Army becomes smaller, some functional areas change, some are transferred to other agencies, and some simply disappear. Specific administrative and human resource oriented functional areas will of necessity remain intact in order to maintain, train, and educate the force. One of these administrative essentials is the review of officer records by a school selection board. This activity is of particular interest during a time of manpower reductions due to the number of experts required to convene a duly constituted board to select candidates to attend military schools. Can the Army afford to continue such labor intensive processes in the face of shrinking budgets and a smaller force? Can a shrinking manpower pool afford to permit a general officer and at least nine other Lieutenant Colonels and Colonels to sit annually on a number of promotion, school selection, and command boards each year for a minimum of five days each?

Completion of Command and General Staff College (CGSC) is one of the imperative elements in an officer's education, training, and career development. This course is designed to educate and train field grade officers (the military equivalent of "middle management") in the operational art of warfare. It prepares officers to assume positions of leadership in the military. Selection to attend CGSC in residence is a sought-after assignment and represents a distinct accolade for those officers intent upon making the Army a career. Resident enrollment at CGSC is limited therefore a selection process is required to choose specific individuals who, based upon their records, merit the opportunity to attend the ten month course. The best qualified individuals are chosen from a candidate pool which is derived

from a window of specific basic year groups. CGSC can be done using the corresponding studies option, however, the value and prestige of attending the Army's CGSC or other Military Education Level 4 (MEL 4) school is undisputed among the officer rank and file as it signifies the trust and confidence that a selection board has regarding the capabilities of those chosen.

The procedures and composition of the CGSC selection board are defined by Deputy Chief of Staff for Personnel (DCSPER) Officer Selection Board Support Standard Operating Procedure[1], Army Regulation 351-1 (Individual Military Education and Training)[2], Department of the Army Pamphlet 600-3 (Commissioned Officer Professional Development and Utilization)[3], Officer Personnel Management Division Operating Instruction 351-1(4) (Command and General Staff College Selection and Slating System)[4], and annual board guidance. Records of officers in the Army Competitive Categories (ACC) are boarded at one time while the records of officers in the special branches (Army Medical Department (AMEDD), Judge Advocate General Corps (JAG), and Chaplains Corps) are boarded separately. The Special Branch records are reviewed by a panel comprised of officers who represent not only the special branch under consideration, but also representatives of the ACC as well.

The board process for CGSC selection consists of two distinct elements. First, all records are screened by the entire board and simply voted as *Yes* or *No*. In general, a *Yes* vote means that the officer is fully qualified for consideration; a *No* vote indicates that the reviewing board member finds that officer not qualified to be considered for CGSC. The amount of time that this first cut of records takes is dependent upon the number of records in

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the pool, but an average length of time that is recommended to review each record during this phase is less than three minutes.

During my personal experience on a selection board, the board president suggested that no more than 90 seconds be spent considering each file. Board members were expected to review a photograph, a hard copy of the Officer Record Brief (ORB), a hard copy of the most recent Officer Efficiency Report (OER), and a companion microfiche (which consists of microfilmed copies of all other existing OER's, letters of commendation and/or reprimand, and copies of all award certificates) in a very short period of time. The ORB alone has 11 detailed sections with numerous subordinate fields of data to be visually scanned by each board member.

The second portion of the CGSC board procedure is the hard vote. After each record has been reviewed by every board member, a report is generated which tallies the number of *Yes* and *No* votes per record. In general, a record will proceed to the hard vote portion of the board process if at least one-half of the board members have voted *Yes* on it. *No* records are dropped from consideration at this point. Board members then proceed by rating the remaining records on a scale of 1 through 6. Pluses and minuses may be included at this time to differentiate between similar records.

Once the hard vote is complete, the board secretary provides the board members with an order of merit list (OML). The OML is compiled by summing the numeric votes from the board members for each individual record. The officer receiving the highest vote count is at the top of the list, the person receiving the next highest total is second, and so on. Pluses and minuses are reflected on the OML lists and contribute to the overall ranking of the

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officers. The final CGSC selections are based upon the OML and are dependent upon the number of seats available by branch specialty.

Statement of the Problem

Due to its downsized force, the Army can ill afford to have a large number of officer experts spending significant manhours reviewing personnel records. The nature and process of the first cut of the school selection process demonstrates a real potential for the development of a computerized system to perform the expert function of initial record review.

Problem Statement

The purpose of the study was to begin the development and testing of an Expert System (ES) to screen officer personnel records being considered for CGSC. The relatively short time allotted for human decision-making about a large number of records during a selection board poses a time problem for many human experts but would not for an expert system. Specifically an ES designed to utilize a scanning mechanism could review significantly more data elements in a much shorter time. It is theoretically possible that an expert system could be designed to support the decision making process, eliminate one step of the process, but not replace the human expert in the final stage of the hard vote.

Research Question

The following research question was addressed in this study: can an expert system be useful to accurately select individuals for the hard vote during the CGSC board selection process?

During the conduct of this study, an ES was considered and tested as a support mechanism for the human decision maker. As such, the system was designed to provide the user with reasons specific records were rated *No*, allowing for manual override by the human experts.

Strategic Significance of the Study

At the United States Army War College (USAWC), strategic leadership is defined as "the process used by a leader to affect the achievement of a desirable and clearly understood vision by influencing organizational culture, allocating resources, directing through policy and directives, and building consensus"[5]. Using this definition, leaders looking at the school selection process would be considered to be thinking and planning strategically if they risked changing the present system by envisioning a new way to allocate and make use of limited resources (board members). By directing new policy toward the development and utilization of existing high technology capabilities, a long standing decision paradigm could be reshaped and improved.

Review of the Literature

Understanding the process of developing an expert system is dependent upon a general exposure to the field of artificial intelligence (AI). Toward this goal, a review of the relevant AI literature was made as related to human resource management (HRM). This review includes definitions of artificial intelligence and expert systems, descriptions of ES uses in the military and in HRM, and a discussion of the potential uses and the limitations of ES in the personnel field.

Artificial Intelligence and Expert Systems

Artificial intelligence (AI) has been defined in numerous ways ranging from the very technical to the very practical. Charniak and McDermott define AI as "the study of mental faculties through the use of computational models"[6]. Shortliffe describes it even more practically as "the intelligence of any machine that performs a task that a century ago would have been considered a uniquely human intellectual ability"[7].

In general, AI researchers seek to represent human knowledge in an electronic or computerized environment. More specifically, AI is a sub-domain within the computer science field which relies on symbolic reasoning and heuristics (rules of thumb) rather than on simple mathematical calculations or routine data retrieval. An obviously complex area of science, artificial intelligence has been employed in many fields such as mathematics, engineering, theorem proving, and robotics.

The artificial intelligence application most commonly connected with decision-making is referred to as an expert system. An expert system is "a computing system which embodies organized knowledge concerning some specific area of human expertise, sufficient to perform as a skillful and cost-effective consultant"[8]. The technology behind the development of expert systems is known as knowledge engineering; expert systems have been described as rule-based, knowledge-based, or expert consulting systems. Expert systems are dependent upon an *inference engine* (a mechanism by which the computer manipulates the rules which have been programmed to deduce inferences or to make diagnoses) and a *knowledge base*. An inference engine may be re-used in a variety of systems, however, the knowledge base of an expert system is usually domain specific to that particular application only.

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Expert Systems in the Military

Expert systems are being explored and utilized in the military in a number of ways. Most of the applications relate to military intelligence, command decision making, instruction, and data-base management[9]. Other smaller systems have also been developed to handle HRM issues such as the slating procedures for the Senior Service College fellowships.[10] The impact of AI and ES in the military is acknowledged and as General Maxwell Thurman attested, "[t]he development of automated support [for the Army], resting in part on the application of artificial intelligence and related techniques...is essential to the successful planning, support, and operation of numerically outnumbered and dispersed forces"[11].

Expert Systems in Human Resource Management

Seaman states, "(t)he major purpose of expert systems is to help people make decisions"[12]; it is logical therefore that many expert systems have been developed for use specifically in the HRM field. Byun and Suh[13] provide an excellent overview of the ways in which ES can be successful in assisting managers in critical decision making. They suggest that the HRM domains of planning, job analysis, recruitment, selection, performance evaluation, compensation, training, and labor-management relations are the most appropriate for the development of ES.

Several of the specific systems which have been developed in the HRM arena will be described in the following paragraphs and include the *Service Selection Advisor*[14], *Organizational Consultant*[15], *Resumix*[16], and *EXPER*[17]. While not an inclusive or exhaustive listing of ES available, this sample of existing programs introduces the utility of ES in HRM.

Service Selection Advisor (SSE) was developed by researchers at Virginia Polytechnic Institute and State University primarily to "support the career field choices made by senior midshipmen in Naval ROTC programs"[18]. The program had a secondary purpose of decreasing the advising load of the ROTC faculty. SSE assisted midshipmen in choosing career fields by analyzing results of a narrative summary of the student, a physical exam, and a security questionnaire balanced against six branch choices of the student. This rule-based system was developed using archival files of previous selections and specific mathematical equations derived from the factors noted above. The developers were pleased with the outcomes of the ES advising. They reported that the ES "performs as well as human advisors in evaluating a midshipman's chances for being selected for a particular designator"[19].

Organizational Consultant was designed to assist in organizational structure decisions. Its knowledge base of 250-plus rules represents an ES attempt to match an appropriate organizational structure with a stated or given organizational environment. The system's decision output includes information regarding the structure, formalization, complexity, and span of control recommended for the organization under consideration.

Resumix demonstrates the capability of an ES to evaluate a resume or job application. This particular system is connected to an optical scanner and facilitates the processing of huge numbers of resumes at a very fast rate. According to Booker[20], this system saves time in the review of applications and has the ability to keep the information from those documents in a database for access, retrieval, and evaluation at any time. The system was reported to have been used by the Clinton White House to wade through volumes of resumes

for positions in the new administration[21].

One final example of a working ES in HRM is a system named EXPER. This system was developed as part of an overall human resource management system with a particular focus on accurate and appropriate job placement. EXPER evaluates employees in order to match their aptitudes with specific jobs within an organization. Test scores, educational levels, performance ratings, and aptitude scores are among the variables entered into the database and considered by the ES to assist managers in making placement decisions.

Potential Uses and Limitations of ES in HRM

As more and more firms downsize, the field of HRM appears to be prime for the development of ES applications. At the same time, the limitations of such systems must be assumed up front and corrected for if necessary in an effort to keep the *person* in the personnel department.

A long laundry list of capabilities and benefits for ES can be easily compiled. Increased productivity, consistent performance, and institutionalized expertise are among the system capabilities embedded into specific programs[22]. ES have the potential to assist with a wide variety of tasks including matching people to jobs, planning career paths, selecting new employees, and training new and old employees[23]. In addition, the capability of an expert system to explain its decision making process is an added benefit to the system user. ES generated explanations are especially useful to a manager who is first and foremost assisted by the computer in the decision making process and is then able secondarily to learn how and why a particular decision was made. The explanatory mode of such systems also works as a double-check or safeguard and permits the human user to override the computer decision

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making if the reasoning is inaccurate or subject to an exception to policy.

Nonetheless, there can be limitations to some expert systems. Limitations include incorrect knowledge, difficulty in obtaining knowledge from the appropriate experts, difficulty representing that knowledge in a computer model, lack of the computer's ability to learn, and a normal human fear of the computer taking over the decision making process[24]. Some of the limitations of ES can be overcome by proper utilization and user expectation. Systems which are designed to be support systems should not be expected to be otherwise. In addition, Illovsky points out that some limitations (such as ES not being able to handle complex cognitive tasks or the inability of the systems to learn) can be overcome by expert programming and system maintenance[25].

Methodology

This study was conceived as a result of personal experiences on a Department of the Army Command and General Staff Selection Board. The process, at least the first vote, seemed to be an example of a problem well suited to assistance from an expert system. Selecting fully qualified records appeared to meet at least two of the problem selection criteria set forth by Mockler and Dologite[26]. Those criteria were: 1) the human expertise was expensive in relation to the job's value; and 2) the job requirements (such as speed and precision) exceeded the capacity of normally available experts. One general officer, six colonels, and three lieutenant colonels comprised the board membership and several of the members struggled to keep up the pace of the Yes/No record review.

An ES is developed according to a logical plan which includes the problem selection,

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knowledge acquisition, knowledge representation, knowledge encoding, knowledge testing and evaluation, and implementation and maintenance[27]. The following sequence of events led to the initial development of the ES named Board Expert (BOARDEX).

Knowledge acquisition is the process of acquiring and organizing the knowledge to be used in a knowledge-based system. In this instance, knowledge acquisition was a combination of documenting specific criteria for selection outlined in Army Regulations and coupling them with the important elements considered when reviewing an officer's record as defined by a domain expert. The investigator became the domain expert based upon her board experience. She enumerated specific data necessary during the board record review and the hierarchical relationships between elements were established. Questions were constructed and decision matrices based upon binary answers to them were generated. Table 1 represents the factors considered.

Knowledge representation was accomplished with the help of CPT Thomas Galvin, a staff member from the Knowledge Engineering Group, Center for Strategic Leadership, United States Army War College. CPT Galvin suggested using PROLOG[28] as the basis for this system. He pointed out that PROLOG is particularly effective when the decision process is primarily binary. Questions and the hierarchical relationships between them were refined on several occasions. Decision matrices were devised. Failure to meet hard and fast (regulatory) criteria for selection yielded immediate *non-selection* decision; failure to meet other discretionary factors yielded a *maybe* response. Maybe responses required linking and qualification by other data elements. Very simple heuristics regarding awards, deployment history, and job descriptions were devised but proved to be the most difficult procedure.

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Ultimately this process was accomplished by defining which data elements constitute a plus or a minus for a record. A percentage of possible awards and/or earned badges documented in the record was then established as a cut off-point.

```
Grade
              Y/N    = or > CPT (P)?
Active Federal Commissioned Service (AFSC)
              Y/N    < 168 months?
Military Education Level (MEL)
              Y/N    = or < 6?
Photograph
              R    Recent (< 2 years)?
              C    Current (>2 and < 5 years)?
              O    Outdated (> 5 years)?
Height/Weight
              Y/N    Meets AR 600-9 standards?
Assignments
              Y/N    Varied?
              Y/N    Command or branch qualified?
OER Part IV
              Y/N    All 1s on last four OERs?
Performance
              Y/N    Left block on last four OERs?
Potential
              Y/N    Left block on last four OERs?
Senior Rater
              Y/N    Top block on last four OERs?
Civilian Education Level (CEL)
              Y/N    = or < 2?
```

Table 1. Factors Considered

Knowledge encoding is the transfer of information to the language of the expert system. This was accomplished by entering data from a set of 15 mock board files obtained

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from the Department of the Army Secretariat, US Total Army Personnel Command (PERSCOM). Each record was reviewed individually and responses to the questions in Table 1 were entered into the PROLOG program. Awards, job descriptions, and deployments were also entered into the ES. During the process, the order of questions was revised to assist with more rapid data entry.

The next step in the process of system development is the knowledge testing and evaluation. This was a two-part strategy and included a comparison between the selections by the expert system and a human expert board. In essence, the human experts were used to validate the selections by BOARDEX.

Thirteen members of the USAWC Class of 1996 reviewed the records and voted them as if they were selection board members. This group was purely a convenience sample and did not reflect any attempt to provide a random sample for statistical purposes. Because three of the 13 were not U.S. Army officers (voter numbers 8, 10, and 12), they were eliminated from the analysis. Of the ten remaining board members, only one had previous board experience, two had mock board experience, and the other seven had no board experience. The board members were briefed as to the voting process, the composition of the records, and counseled as to a limited amount of time to be spent on each record; it was recommended that they spend no more than three minutes on each record. Votes were tallied and results documented. Candidates were considered to be *selected* if they received *Yes* votes from at least five (50%) of the board members.

The second part of the testing and evaluation phase was accomplished by actually running the ES. The selections and comparisons between the ES and the human expert board

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will be provided in the results section of this paper.

The final phase of the development of an ES is implementation and maintenance. Due to the time constraints of the strategic research project, these two functions were well beyond the scope of this paper. In theory, however, in the next step of development, the ES would be implemented using a user friendly interface rather than the complex PROLOG language and adjustments, corrections, and changes would be made to the rules and heuristics based upon changes in policy and practice.

RESULTS

The results of this study can be described as the analysis of the correlations between two separate sets of data. First, the Pearson correlations were calculated between the voters on the human expert panel. Second, correlations were determined between the votes generated by BOARDEX and the human expert board. All statistics were calculated using the Statistical Package for the Social Sciences (SPSS 6.1 for Windows).

The first analysis yielded a large number of statistically significant correlations between individual board members. Raw voting data of both BOARDEX and the 10 human experts is available at Appendix B. Appendix C is a correlation matrix based upon the human expert data. Twenty-six of the possible 45 correlations between voters were statistically significant at $p <$ or $= .05$ level of significance.

The second analysis was more complex. BOARDEX was developed with a capability of determining three categories of record: those which were strongly recommended for hard vote; those which were moderately recommended for hard vote; and those which were

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recommended for immediate nonselection. In everyday terms, these translate into *Yes*,

Maybe, and *No*. In the board setting, the *Maybe* votes will most likely become *Yes* votes

because voters will want to review that file again in more detail during the hard vote. The

votes were therefore correlated in two ways, straight *Yes/No*, and *Yes/Maybe/No*. The

Pearson correlation for the *Yes/No* vote was r=.6614 (p=.007) and for the *Yes/Maybe/No*

was r=.6646 (p=.007) recoding the human expert votes by the number of *Yes* votes per

record. A record was coded *No* if 0-4 board members voted *Yes*, *Maybe* if 5-8 members

voted *Yes*, and *Yes* if 9-10 members voted *Yes*. In addition, cross-tabs were run to determine

an evaluation concordance and are found in Tables 2 and 3. Each of the evaluation

concordances were found to be statistically significant using both Pearson and the Spearman

correlation.

Count Row Percent Column Percent Total Percent	HUMAN EXPERTS NO	HUMAN EXPERTS YES
BOARDEX NO	5 62.5 100.0 33.3	3 37.5 30 20.0
BOARDEX YES		7 100.0 70.0 46.7

Statistic	Value	Approximate Significance*
Pearson's R	.66144	.00724
Spearman Correlation	.66144	.00724

* Significance is based on a normal approximation

Table 2. Evaluation Concordance for Yes/No votes.

Count Row Percent Column Percent Total Percent	HUMAN EXPERTS NO	HUMAN EXPERTS MAYBE	HUMAN EXPERTS YES
BOARDEX NO	5 62.5 100.0 33.3	2 25.0 50.0 13.3	1 12.5 16.7 6.7
BOARDEX MAYBE		1 33.3 25.0 6.7	2 66.7 33.3 13.3
BOARDEX YES		1 25.0 25.0 6.7	3 75.0 50.0 20.0

Statistic	Value	Approximate Significance*
Pearson's R	.66463	.00687
Spearman Correlation	.66484	.00485

* Significance is based on a normal approximation

Table 3. Evaluation Concordance for Yes/Maybe/No votes.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This study demonstrated the utility of a very simple expert system for use in human resource management. Specifically, BOARDEX was successful at selecting those records during a mock CGSC board which would be recommended for further consideration. Highly significant correlations and evaluation concordances between the system and the human experts were encouraging and the process validated the effectiveness and efficiency of ES in HRM.

The number of significant correlations between members of the human expert board demonstrated a high internal consistency for the voting procedure. While there were some outliers, in general the voting was relatively uniform. The *Yes* versus *No* records were easily determined by the voting patterns as many records were either unanimously *Yes* or unanimously *No*.

The significant findings between BOARDEX and the human expert board are encouraging. The evaluation concordance demonstrated a consistency between the two modes of voting that could be improved with further refinement of the system. Intellectually, few board members would have trouble if a computer model were to *select* a record for continued consideration; the difficulty in logic and emotion enters the picture if a computer were to mechanically *non-select* individuals thereby eliminating them from contention. One of the advantages of BOARDEX is that it can explain the reason(s) that someone is non-select. This explanatory mode allows the board to review any records it feels were rejected for inappropriate or nonapplicable reasons. The system can also be prompted to enumerated those records which are found to be either sufficient or insufficient in a particular area. For

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instance, the system is able to list all those individual records whose photograph is outdated or missing.

Limitations of the Study

This study was limited by several factors including the limitation of time for testing and the small number of records obtained from PERSCOM for review. Other limitations were evident regarding the investigator's amateur ability to develop and manipulate the ES programming and language.

Although the inter-rater correlations between the board members was good, factors that may have biased the board included: the nature of the board scenario was contrived because the records reviewed were actually a Major to Lieutenant Colonel promotion board set not actual CGSC records; no quota or goal for selection was established; and the board members did not go through a calibration of their voting. A confounding factor in the data entry of the ES was that the photographs were totally out of date. They ranged in date from 1988 through 1991 and were totally unacceptable with regard to the standards established in the decision matrix and current doctrine. This was corrected in BOARDEX by establishing specific years for the categories recent, current, and outdated, but this was a variance from the original design of the ES. A method to concurrently test an ES with actual, current records would be of value.

Recommendations

After working with this system and talking with experts in the field of AI, it is

obvious to the investigator that BOARDEX is really not an ES but truly at the level of a decision support system. Several recommendations for further work and research could help to enhance the system and to increase not only its decision capability but also its usefulness in military HRM.

First, a user interface for the system should be developed. If BOARDEX is to be helpful in cutting down the use of high ranking manpower to screen records prior to a hard vote, the access to the program must be logical, user friendly, and relatively fast. Ideally the system could interface with the existing PERSCOM data base which generates the ORB. An additional advantage would be to couple the ES with an optical scanner as was done with Resumix, to read the OERs and ORBs and speed up data entry.

Second, a better system would include more sophisticated heuristics to differentiate between records. In order to accomplish this, a panel of experts could be surveyed and a decision hierarchy agreed upon. In addition, a more sophisticated decision system would be able to analyze the relationship and timing of important criteria and weigh the relative merit of specific senior raters.

A final recommendation is to revise the system until it is detailed and discriminating enough to provide a computer scan of the records for the hard vote. This would save time for the board members who must juggle the microfiche reader and hard copies of documents in order to make an informed decision.

PROLOG Source Code Listing

```
run :-
    bagof(X,select(X),SelectList),
    write('The following are strongly recommended for hard
vote:'), nl,
    for_each_write(SelectList),
    bagof(n(X̄,L),nonselect(X,L),NonSelectList),
    write('The following are recommended for immediate
nonselection:'), nl,
    for_each_write(NonSelectList),
    bagof(n(X̄,L),maybe(X,L),MaybeList),
    write('The following are moderately recommended for hard
vote:'), nl,
    for_each_write(MaybeList).

select(X) :-
    candidate(X),
    meets_immediate_screening_requirements(X),
    meets_photo_standards(X),
    meets_height_weight_standards(X),
    not(meets_ar_600_9_via_body_taping(X)),
    meets_assignment_standards(X̄),
    no_bad_oers(X).

nonselect(X,ReasonL) :-
    candidate(X),
    bagof(HL,nonselect1(X,HL,hell_no),L1), nice_append(L1,L1A),
    bagof(ML,nonselect1(X,ML,maybe),L2), nice_append(L2,L2A),
    append(L1A,L2A,L3), nonselect0(X,L1A,L3,ReasonL).
nonselect0(_,L1A,ReasonL,ReasonL) :- not(same(L1A,[])), !.
nonselect0(X̄,[],ReasonL,[plusses_dont_offset|ReasonL]) :-
   not(plusses_offset_all_nonselect_reasons(X,ReasonL)), !.

nonselect1(X,ReasonL,hell_no) :-
    fails_immediate_screening_requirements(X,ReasonL).
nonselect1(X,outdated_photo,maybe) :-
    fails_photo_standards(X).
nonselect1(X,height_weight,hell_no) :-
    not(meets_height_weight_standards(X)).
nonselect1(X,assignments,hell_no) :-
    fails_assignment_standards(X).
nonselect1(X,multiple_bad_oers(OERL),hell_no) :-
    setof(bad_oer(P,OER),bad_oer(X,P,OER),OERL),
same(OERL,[_,_|_]).

maybe(X,ReasonL) :-
    candidate(X),
    not(select(X)),
```

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```prolog
   not(nonselect(X,_)),
   bagof(HL,nonselect1(X,HL,hell_no),[]),
   bagof(ML,nonselect1(X,ML,maybe),L1), nice_append(L1,L1A),
   bagof(NL,maybe1(X,NL),L2), nice_append(L2,L2A),
   append(L1A,L2A,L3), maybe0(X,L1A,L3,ReasonL).
maybe0(_,[],ReasonL,ReasonL) :- !.
maybe0(X,L1A,ReasonL,[plusses_offset|ReasonL]) :-
   not(same(L1A,[])), plusses_offset_all_nonselect_reasons(X,L3),
   !.

maybe1(X,body_fat) :-
   meets_height_weight_standards(X),
   meets_ar_600_9_via_body_taping(X).
maybe1(X,ReasonL) :-
   maybe_assignment_standards(X,ReasonL).
maybe1(X,one_bad_oer(bad_oer(P,OER))) :-
   setof(OER,P^bad_oer(X,P,OER),[_]),
   bad_oer(X,P,OER).

meets_immediate_screening_requirements(X) :-
   promotion_eligible_captain(X),
   afsc(X,AFSC1), AFSC1<230,
   mel(X,MEL1), greater_than_MEL_6(MEL1).
meets_immediate_screening_requirements(X) :-
   major(X),
   afsc(X,AFSC1), AFSC1<230,
   mel(X,MEL1), greater_than_MEL_6(MEL1).

greater_than_MEL_6(X) :- member(X,[n,6,4,2]).

fails_immediate_screening_requirements(X,ineligible) :-
   not(promotion_eligible_captain(X)), not(major(X)).
fails_immediate_screening_requirements(X,beyond_window) :-
   afsc(X,AFSC1), AFSC1>=230.
fails_immediate_screening_requirements(X,education) :-
   mel(X,MEL1), not(greater_than_MEL_6(MEL1)).

meets_photo_standards(X) :-
   photo(X,recent).
meets_photo_standards(X) :-
   photo(X,current).
fails_photo_standards(X) :-
   not(photo(X,_)).
fails_photo_standards(X) :-
   photo(X,outdated).

/* meets_height_weight_standards is a database fact */

meets_assignment_standards(X) :-
   has_varied_assignments(X),
   branch_qualified(X).
```

```prolog
fails_assignment_standards(X) :-
   not(has_varied_assignments(X)),
   not(branch_qualified(X)).

maybe_assignment_standards(X,varied) :-
   branch_qualified(X),
   not(has_varied_assignments(X)).
maybe_assignment_standards(X,branch_qual) :-
   has_varied_assignments(X),
   not(branch_qualified(X)).

no_bad_oers(X) :- not(bad_oer(X,_,_)), !.
no_bad_oers(X) :- bad_oer(X,P,BOER), is_an_oer(X,GOER),
not(same(BOER,GOER)),
   offset_bad_oer(X,GOER,BOER), !.

good_oer(X,OER) :- above_center_of_mass_OER(X,OER).
good_oer(X,OER) :- at_center_of_mass_OER(X,OER).

bad_oer(X,performance,OER) :- performance_rating(X,OER,PERF),
not(same(PERF,left_column)).
bad_oer(X,potential,OER)   :- potential_rating(X,OER,POTN),
not(same(POTN,left_column)).
bad_oer(X,part_IV,OER)     :- part_IV_rating(X,OER,PTIV),
not(same(PTIV,all_1s)).
bad_oer(X,below_center_of_mass,OER) :-
   senior_rating(X,OER,RATING),
   senior_rater(X,OER,SRATER,RANK),
   below_center_of_mass(RATING,SR_RATER).

offset_bad_oer(X,OER1,OER2) :-
   good_oer(X,OER1), senior_rater(X,OER1,SRATER1,go),
   senior_rater(X,OER2,SRATER2,not_go).
offset_bad_oer(X,OER1,OER2) :-
   good_oer(X,OER1), senior_rater(X,OER1,SRATER,_),
   senior_rater(X,OER2,SRATER,_),
   more_recent_than(OER1,OER2).

plusses_offset_all_nonselect_reasons(_,[]).
plusses_offset_all_nonselect_reasons(X,[R|RL]) :-
  plusses_offset_nonselect(X,R),
  plusses_offset_all_nonselect_reasons(X,RL).
plusses_offset_all_nonselect_reasons(_,_) :- !, fail.

plusses_offset_nonselect(X,outdated_photo) :-
  plusses(X,N), N >= 4.
plusses_offset_nonselect(X,part_III(_)) :-
  plusses(X,N), N >= 3.
plusses_offset_nonselect(X,part_IV(_)) :-
  plusses(X,N), N >= 3.
plusses_offset_nonselect(X,_) :- !, fail.
```

```prolog
plusses(X,N) :- bagof(P,has_a_plus(X,P),PL), length(PL,N).
has_a_plus(X,cel) :- cel(X,1).
has_a_plus(X,cel) :- cel(X,2).
has_a_plus(X,cel) :- cel(X,3).
has_a_plus(X,badge1) :- bagof(B,earned(X,B),[_|_]).
has_a_plus(X,badge2) :- bagof(B,earned(X,B),[_,_|_]).
has_a_plus(X,deployment_experience) :-
has_deployment_experience(X,W).
has_a_plus(X,general_aide) :- duty_title(X,OER,general_aide).
has_a_plus(X,pentagon_badge) :- award(X,pentagon_badge).

for_each_write([]).
for_each_write([X|L]) :- atomic(X), write('  '), write(X), nl,
for_each_write(L).
for_each_write([n(X,XL)|L]) :- write('  '), write(X), write(',
because:'), nl,
    for_each_write1(X,XL), for_each_write(L).
for_each_write1(_,[]).
for_each_write1(X,[plusses_offset|L]) :- write('    '),
    explanation(plusses_offset,XE), write(XE), nl,
for_each_write1(X,L),
    write('    The following were the offsetting items:'), nl,
    write_plusses(X).
for_each_write1(X,[E|L]) :- explanation(E,''),
for_each_write1(X,L).
for_each_write1(X,[E|L]) :- explanation(E,XE), not(same(XE,'')),
    write('    '), write(XE), nl, for_each_write1(X,L).
write_plusses(X) :- setof(B,has_a_plus(X,B),BL),
    ((member(badge2,BL),delete(badge1,BL,BLL));same(BL,BLL)),
write_plusses1(BLL).
write_plusses1([]).
write_plusses1([B|BL]) :- write('        + '), explanation(B,BE),
write(BE), nl,
    write_plusses1(BL).


explanation(plusses_dont_offset,'The officer''s special
qualifications did not offset the below problems.').
explanation(plusses_offset,'The officer''s special qualifications
offset the below problems.').
explanation(ineligible,'Officer is not a promotion-eligible
captain.').
explanation(beyond_window,'Officer has already been considered
four times.').
explanation(education,'Officer has not met military education
requirements.').
explanation(outdated_photo,'Photo is over five years old.').
explanation(height_weight,'Fails to meet height and weight
standards.').
explanation(assignments,'Has not met branch requirements for
assignments.').
```

```prolog
explanation(varied,'Has not sufficiently varied assignments.').
explanation(branch_qual,'Has not held command or other branch
qualifying position.').
explanation(body_fat,'Required taping to meet AR 600-9
standards.').
explanation(multiple_bad_oers(OERL),'') :-
   write('   Officer has more than one weak OER among last
four.'), nl,
   write_plusses1(OERL).
explanation(one_bad_oer(OER),'') :-
   write('   Officer has one weak OER among last four.'), nl,
   write_plusses1([OER]).
explanation(bad_oer(performance,OER),'') :-
   write('The performance block of OER #'), write(OER),
   write(' is checked away from the left column.').
explanation(bad_oer(potential,OER),'') :-
   write('The potential block of OER #'), write(OER),
   write(' is checked away from the left column.').
explanation(bad_oer(part_IV,OER) :-
   write('OER #'), write(OER), write('has non-1 ratings on the
front side.').
explanation(bad_oer(below_center_of_mass,OER),'') :-
   write('The senior rater rated the officer below center of mass
on OER #'),
   write(OER), write('.').
explanation(cel,'Civilian education level').
explanation(badge1,'Earned one special qualification badge (ABN,
SF, AASLT, etc.)').
explanation(badge2,'Earned two special qualification badges (ABN,
SF, AASLT, etc.)').
explanation(deployment_experience,'Has deployment experience').
explanation(generals_aide,'Served as a General''s Aide-de-Camp').
explanation(pentagon_badge,'Earned the Pentagon Badge.').


goof(X,missing_mel,'mel(<name>,<mel>)') :-
   candidate(X), not(mel(X,_)).
goof(X,missing_rank,'captain(<name>),
promotion_eligible_captain(<name>), or major(<name>)') :-
   candidate(X), not(captain(X)),
not(promotion_eligible_captain(X)),
   not(major(X)).
goof(X,missing_afsc,'afsc(<name>,<# of months in service>') :-
   candidate(X), not(afsc(X,_)).
goof(X,bad_afsc,'afsc(<name>,<# of months in service (numeric)>')
:-
   candidate(X), afsc(X,Y), not(number(Y)).
goof(X,bad_photo_status,'photo(<name>, recent or current or
outdated)') :-
   candidate(X), photo(X,Y), not(same(Y,current)),
not(same(Y,recent)),
```

```
    not(same(Y,outdated)).
goof(X,missing_oer_data(Y),'duty_title(<name>, <oer>, <title>)')
:-
    candidate(X), is_an_oer(X,Y), not(duty_title(X,Y,_)).
goof(X,missing_oer_data(Y),'performance_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), not(performance_rating(X,Y,_)).
goof(X,bad_oer_data(Y),'performance_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), performance_rating(X,Y,P),

not(member(P,[left_column,second_column,third_column,right_column
])).
goof(X,missing_oer_data(Y),'potential_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), not(potential_rating(X,Y,_)).
goof(X,bad_oer_data(Y),'potential_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), potential_rating(X,Y,P),

not(member(P,[left_column,second_column,third_column,right_column
])).
goof(X,missing_oer_data(Y),'part_IV_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), not(part_IV_rating(X,Y,_)).
goof(X,bad_oer_data(Y),'part_IV_rating(<name>, <oer>, <rating>)')
:-
    candidate(X), is_an_oer(X,Y), part_IV_rating(X,Y,P),
    not(member(P,[all_1s,some_2s])).
goof(X,missing_oer_data(Y),'senior_rating(<name>, <oer>,
<rating>)') :-
    candidate(X), is_an_oer(X,Y), not(senior_rating(X,Y,_)).
goof(X,bad_oer_data(Y),'senior_rating(<name>, <oer>, <rating>)')
:-
    candidate(X), is_an_oer(X,Y), senior_rating(X,Y,P),

not(member(P,[top_block,second_block,third_block,fourth_block,fif
th_block])).
goof(X,missing_oer_data(Y),'senior_rater(<name>, <oer>, <rater>,
<rank>)') :-
    candidate(X), is_an_oer(X,Y), not(senior_rater(X,Y,_,_)).
goof(X,bad_oer_data(Y),'senior_rater(<name>, <oer>, <sr_rater>,
<rank>)') :-
    candidate(X), is_an_oer(X,Y), senior_rater(X,Y,SR,RK),
    not(member(RK,[go,not_go])).
goof(X,missing_sr_data(SR),'center_of_mass(<sr_rater>, <block>)')
:-
    candidate(X), is_an_oer(X,Y), senior_rater(X,Y,SR,_),
    not(center_of_mass(SR,_)).
goof(X,bad_sr_data(SR), 'center_of_mass(<sr_rater>, <block>)') :-
    candidate(X), is_an_oer(X,Y), senior_rater(X,Y,SR,_),
```

```prolog
      center_of_mass(SR,RK),

not(member(RK,[top_block,second_block,third_block,fourth_block,fi
fth_block])).

is_an_oer(X,Y)  :- candidate(X),
setof(OER,is_an_oer1(X,OER),OERL),
   member(Y,OERL).
is_an_oer1(X,Y)  :- duty_title(X,Y,_).
is_an_oer1(X,Y)  :- performance_rating(X,Y,_).
is_an_oer1(X,Y)  :- potential_rating(X,Y,_).
is_an_oer1(X,Y)  :- part_IV_rating(X,Y,_).
is_an_oer1(X,Y)  :- senior_rating(X,Y,_).
is_an_oer1(X,Y)  :- senior_rater(X,Y,_,_).

append([],L,L).
append([X|M],L,[X|L1])  :- append(M,L,L1).
delete(X,[],[]).
delete(X,[X|L],L).
delete(X,[Y|L],[Y|L1])  :- delete(X,L,L1).
member(X,L)  :- append(_,[X|_],L).
nice_append([],[])  :- !.
nice_append([X|L],[X|L3])  :- not(is_list(X)), nice_append(L,L3),
!.
nice_append([L|L2],L3)  :- is_list(L), nice_append(L,L5),
nice_append(L2,L6),
   append(L5,L6,L3), !.
is_list([]).
is_list([_|_]).
length([],0).
length([X|L],N)  :- length(L,N1), N is N1+1.
same(X,X).
```

APPENDIX B

Vote Data

	BOARDEX	VOTER1	VOTER2	VOTER 3	VOTER 4	VOTER 5	VOTER6	VOTER 7	VOTER9	VOTER11	VOTER13
FILE A	N	Y	N	N	N	N	N	N	N	Y	N
FILE B	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N
FILE C	N	Y	N	N	Y	N	N	Y	Y	Y	Y
FILE D	N	N	N	N	N	N	N	N	N	N	N
FILE E	Y	Y	Y	N	Y	Y	N	Y	Y	N	N
FILE F	N	Y	N	N	Y	N	N	Y	N	Y	Y
FILE G	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FILE H	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FILE I	N	Y	Y	N	N	N	N	Y	N	N	Y
FILE J	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FILE K	N	N	N	N	N	N	Y	Y	Y	N	N
FILE L	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FILE M	N	N	N	N	N	N	N	N	N	N	N
FILE N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
FILE O	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

APPENDIX C

Pearson Correlation Matrix

Human Expert Votes

	1	2	3	4	5	6	7	9	11	13
1	1.00									
2	.61*	1.00								
3	.41	.67*	1.00							
4	.71*	.58*	.58*	1.00						
5	.53*	.87*	.76*	.76*	1.00					
6	.13	.49	.60*	.38	.61*	1.00				
7	.45	.43	.49	.53*	.34	.26	1.00			
9	.35	.58*	.58*	.70*	.76*	.66*	.53*	1.00		
11	.71*	.29	.58*	.70*	.47	.38	.21	.40	1.00	
13	.61*	.44	.67*	.58*	.32	.22	.74*	.29	.58*	1.00

* p < or = .05

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